Accident Analysis and Prevention 37 (2005) 1040–1048

ACCIDENT ANALYSIS & PREVENTION

www.elsevier.com/locate/aap

Fatalities in Swedish skydiving

Anton Westman*, Ulf Björnstig

Department of Surgical and Perioperative Sciences, Division of Surgery, Umeå University, SE-901 85 Umeå, Sweden

Received 7 December 2004; received in revised form 11 May 2005; accepted 2 June 2005

Abstract

Exact risk patterns in skydiving fatalities are not well known, but incomplete world injury data indicate that many are preventable. A comprehensive national material for Sweden of 37 skydiving fatalities 1964–2003 were reviewed to identify risk factors. In relation to jump volume, the period 1994–2003 had a fatality rate 11 times lower than 1964–1973. Student skydivers had the highest risk of fatal outcome, often caused by instability in freefall leading to unstable parachute activation with subsequent line entanglement, or parachute activation failure. Unintentional water landings also contributed to student fatality, with life jacket malfunctions, neglect to use life jackets, and automatic reserve parachute activation devices activated by water as aggravating factors. One-third of all fatalities had an inflated and operational parachute at some point prior to injury. A drastic worldwide increase in fatal landing incidents with fast wing parachutes during the 1990s did not occur in Sweden. Every fourth fatality caused by rapid deceleration against ground or water survived impact and died during transports or in hospitals. Rescue units and health care providers can improve management of skydiving incidents from knowledge about the incident and injury mechanisms we have described, and the skydiving community can target risk factors in preventive safety work.

Keywords: Skydiving; Sport parachuting; Fatal injuries; Epidemiology; Risk factors; Safety

1. Introduction

Although the first recorded parachuting death occurred as early as July 24, 1837 (Lucas, 1997), very few systematic studies of fatal parachuting injuries have been made. Given that a somewhat astonishing 94% of known sport parachuting fatalities in the world during 2002 happened with the jumper still having at least one good parachute on his or her back (International Parachuting Commission, 2003), it would seem that many could have been prevented.

Sport parachuting from aircraft is a competitive and recreational activity commonly known as skydiving, enjoyed by participants of both sexes and all ages in 118 countries. Skydiving is an Olympic applicant and the growing total number of sport parachutists is estimated to be over 675,000 (Hilfiker et al., 2002). Almost any adult of reasonable health can sign up for a skydiving course or a tandem jump, and more than 5.77 million jumps were made worldwide during 2002 (International Parachuting Commission, 2003).

Most studies of parachuting traumas have investigated injuries in military parachuting (Tobin et al., 1941; Lord and Coutts, 1944; Essex-Lopresti, 1946; Ciccone and Richman, 1948; Kiel, 1965a; Mellen and Sohn, 1990; Amoroso et al., 1997, 1998; Bricknell and Craig, 1999; Schumacher et al., 2000; Knapik et al., 2003). These data are not fully applicable on civilian parachuting, as civilian and armed forces parachuting differ in important aspects such as demography, training, environmental conditions for jumping and parachute flight characteristics. Civilian investigations have mainly focused on non-fatal injuries (Petras and Hoffman, 1983; Amamilo et al., 1987; Ellitsgaard, 1987, 1988; Steinberg, 1988; Ellitsgaard et al., 1989; Dawson et al., 1998; Baiju and James, 2003; Barrows et al., 2005), overlooking the distinct incident and injury mechanisms of fatalities. Addressing this lack of systematism for fatal injuries, Hart and Griffith (2002) developed a skydiving fatality taxonomy to discriminate between technical malfunctions and operator errors. They found that between 1986 and 2001, 507 people in the United States had died from injuries sustained in skydiving, with a marked increase in landing fatalities with open parachute and fully functional gear, but without change of

* Corresponding author. Tel.: +46 702 202 557; fax: +46 90 771755.
E-mail address: anton@worldwidewestman.com (A. Westman).

0001-4575/$ – see front matter
doi:10.1016/j.aap.2005.06.002

overall fatality rate (Hart and Griffith, 2003), implying altered risk patterns during the time period. The few other studies of skydiving fatalities made have also indicated distinct and presumably preventable risk patterns. Notably, one-third of documented deaths in civilian sport parachuting in the United States between 1956 and 1964 involved student skydivers (Kiel, 1965b), and were mostly attributed to insufficient training (Ryan and Thomas, 1965). In relation to gender ratio of participants, women were over-represented in fatal parachute incidents in Australia between 1960 and 1974, and some skydiving equipment in the early 1970s was unsuited for females lacking muscular strength to exert parachute activation pull force (Bullock, 1978).

The Swedish Parachute Association, the world's seventh largest in number of jumps (International Parachuting Commission, 2003), maintains central records on skydiving fatalities, providing a comprehensive national material for study.

1.1. Aim of the study

The present study aimed to describe the epidemiology of fatal incidents in Swedish skydiving 1955–2003 in order to create a basis for prevention.

2. Materials

The Swedish Parachute Association regulates civilian parachuting from aircraft in Sweden, and conducts investigations on skydiving fatalities on behalf of the Swedish Civil Aviation Administration. The investigation material contains technical data, police reports, post mortem autopsy records and photographic documentation. All archived investigation material 1955–2003 was reviewed. Complementary information was obtained from local departments of forensic medicine, the Swedish Civil Aviation Administration, the International Parachuting Commission, personal interviews and in the case a fatal civilian jump was performed by a military employee, from the Swedish Parachute Ranger School. The data were considered to be fully comprehensive for fatalities associated with civilian parachuting from aircraft in Sweden between 1955 and 2003.

2.1. Inclusion criteria

Fatalities involving Swedish and foreign skydivers jumping in Sweden were included.

2.2. Exclusion criteria

Airplane crashes and parachuting fatalities in other countries involving Swedish skydivers were excluded. Fatalities associated with parachuting from fixed objects was also excluded, as was a tandem passenger who suffered a fatal acute myocardial infarction during the skydive.

3. Methods

Mechanisms of incident and injury were analyzed examining human, equipment and environment factors, and correlated to demographical and jump data. Where for some years a mismatch was detected between demographical and jump data retrieved from the Swedish Parachute Association and the International Parachuting Commission, data from the Swedish Parachute Association were used. A procedure for analyzing operator performance (Hart and Griffith, 2002) was used, in which incident factors were categorized by three independent raters as one of the following: no pull/low pull, landing, gear failure, incorrect gear, midair collision, medical, incorrect procedures, correct procedures, collapse or flight. Category explications in Table 1. The raters were certified instructors in the Swedish Parachute Association with 12–22 years in the sport and 2300–6200 number of jumps, respectively.

4. Results

4.1. Fatality rate

The first fatal civilian sport parachuting incident in the Swedish Parachute Association was found to have occurred

Table 1
Categorization of 37 skydiving fatalities in Sweden 1964–2003 by three independent raters according to the Hart–Griffith skydiving fatality taxonomy (Hart and Griffith, 2002)

Incorrect procedures (such as wrong sequence of reserve procedure)	14
No pull/low pull	11
Correct procedures (the skydiver did everything right, no apparent gear failure)	6
Midair collision (during freefall or under parachute)	2
Landing (conscious skydiver colliding with ground/object under fully deployed canopy)	2
Incorrect gear (incorrect wearing or configuration)	1
Medical (such as heart attack)	1
Gear failure (mechanical or structural)	0
Collapse (of the parachute at altitude too low for corrective action)	0
Flight (parachute control inputs resulting in failure/loss of control, too low for corrective action)	0
Rater disagreement	6
Total	37

Explications in parentheses as given to raters.

Table 2
Incidence of skydiving fatalities in Sweden 1964–2003

Time period	Fatalities	Jumps	Fatalities per 100,000 jumps
1964–1973	5	58,215	8.6
1974–1983	13	262,037	5.0
1984–1993	10	703,782	1.4
1994–2003	9	1,126,704	0.80
Total	37	2,150,738	1.7

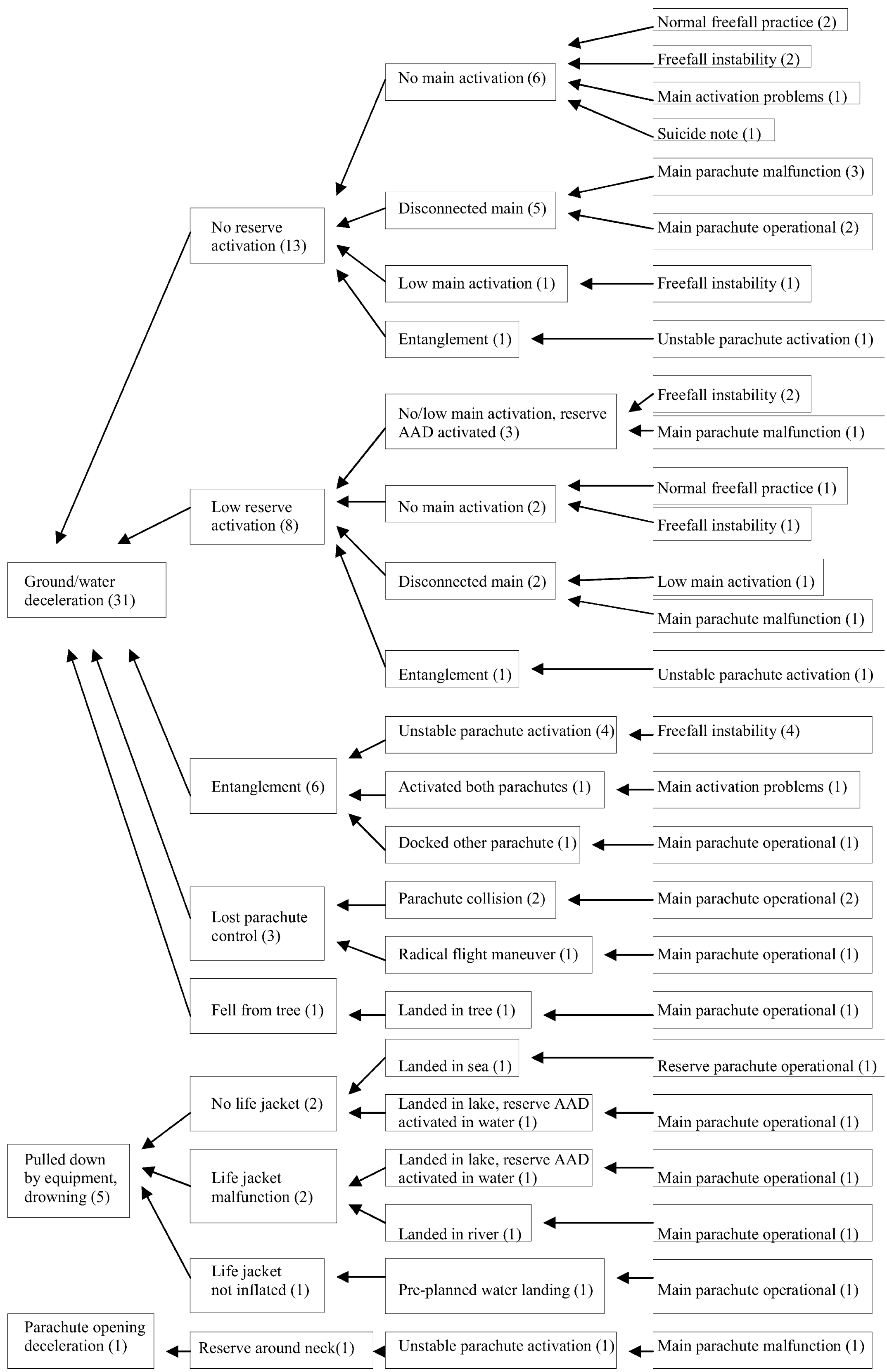

Fig. 1. Summary of most important events leading to 37 skydiving fatalities in Sweden 1964–2003. Operational state of parachute defined as capability to prevent landing injury. AAD: automatic activation device. Unstable parachute activation considered a separate event, though in many cases synonymous to freefall instability. Low parachute activation defined as undertaken at an altitude insufficient for inflation. Where normal freefall practice has been defined as an event, no other known event preceeded the next event.

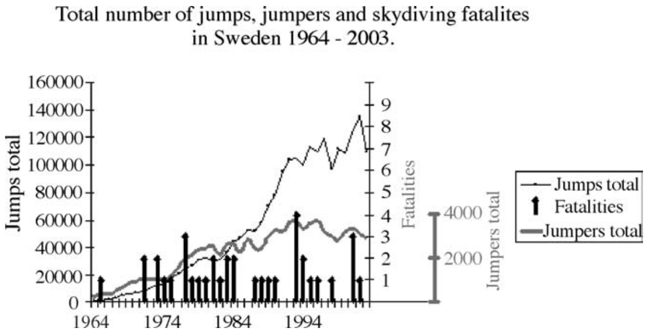

Fig. 2. Total number of jumps, jumpers and skydiving fatalities in Sweden 1964–2003.

in 1965 (Fig. 2). During the 40-year period 1964–2003, 37 fatally injured were included, giving an incidence of 0.9 per year, or 1.7 per 100,000 jumps. During the years 1994–2003, the fatality rate was 0.8 per 100,000 jumps. This was 11 times lower than that during 1964–1973 (Table 2). The annual number of active skydivers 1994–2003 varied between 2780 and 3704, giving a mean annual fatality rate of 28 per 100,000 skydivers and year. This was 2.5 times lower than that during 1964–1973, when the number was 71 per 100,000 skydivers and year.

4.2. Injury mechanisms and injuries

Three primary injury mechanisms could be defined (Fig. 1): ground/water deceleration (31 fatalities), drowning (5) and parachute opening deceleration (1). A human being in freefall without open parachute has a vertical velocity range between 200 and 500 km/h. Consequently, decelerating forces in many of the present cases were awesome. Post mortem autopsy records were found in 22 (59%) cases, showing massive injuries to the central nervous, cardiovascular, respiratory, musculoskeletal and urinary systems, and to the liver, spleen, pancreas and skin. In many cases, more severe injuries were found in body parts having hit the ground first. The ground/water deceleration group included one skydiver who fell into a lake with no parachute inflated and died with severe lacerations of the central nervous system. All cases of ground/water impact in freefall terminal velocity were believed to have died almost instantly. Seven cases in the ground/water deceleration group had a velocity slow enough

Table 3
Gender, experience level in number of jumps and two most important events preceding 37 skydiving fatalities in Sweden 1964–2003

	Total	Male	Female	Preceding events	←
Student in training					
Automatic deployment	5	3	2	Entanglement (2)	Unstable parachute activation (2)
				No/low reserve activation (1)	Main parachute malfunction (1)
				Drowning (1)	Main parachute operational (1)
				Fell from tree (1)	Main parachute operational (1)
Manual deployment	14	13	1	No/low reserve activation (8)	Freefall instability (6)
					Unstable parachute activation (1)
					No/low main activation (1)
				Drowning (3)	Main parachute operational (2)
					Reserve parachute operational (1)
				Entanglement (2)	Freefall instability (1)
					Unstable parachute activation (1)
				Reserve around neck (1)	Main parachute malfunction (1)
Licensed					
≤100 jumps	5	3	2	No/low reserve activation (4)	No/low main activation (3)
					Suicide note (1)
				Lost parachute control (1)	Parachute collision (1)
101–200 jumps	6	4	2	No/low reserve activation (4)	Main parachute malfunction (3)
					Disconnected operational main (1)
				No/low reserve activation (1)	No/low main activation (1)
				Lost parachute control (1)	Radical flight maneuver (1)
201–300 jumps	3	3	–	Entanglement (1)	Activated both parachutes (1)
				No/low reserve activation (2)	Disconnected operational main (1)
					Main parachute malfunction (1)
301–400 jumps	1	1	–	Entanglement (1)	Unstable parachute activation (1)
401–500 jumps	1	1	–	Drowning (1)	Main parachute operational (1)
501–600 jumps					
601–700 jumps					
701–800 jumps	1	1	–	Lost parachute control (1)	Parachute collision (1)
...					
1901–2000 jumps	1	1	–	Entanglement (1)	Docked other parachute (1)
Total	37	30	7		

to survive impact. They died during transports (2) or in hospitals (5). The one case of fatal parachute opening deceleration found had caught the deploying reserve parachute around his neck, and landed under the reserve a few minutes later without spontaneous breathing, with vertebral fractures and injuries to the thyroid cartilage and spinal cord.

4.3. Age, gender and parachute deployment

Mean age of fatally injured was 29 years, range 17–58 years. Seven (19%) were women and five of these women were below the age of 21 years. Data for gender of participants could only be obtained for the 10-year period 1994–2003, during which women annually constituted between 17 and 19% of all skydivers in Sweden. Nine fatalities occurred between 1994 and 2003, of which 2 (22%) were women. Excluding 1 suicide, 4 (57%) of the 7 female fatalities were associated with failure to deploy either parachute, whereas 12 (40%) of the male fatalities were associated with failure to deploy either parachute.

4.4. Experience level

Nineteen (51%) of all fatalities were student skydivers (Table 3). Data for number of students and student jumps could only be obtained for the 10-year period 1994–2003, during which students made 12% of the total number of jumps and annually constituted between 42 and 61% of all skydivers. Of the nine fatalities that occurred between 1994 and 2003, four (44%) were students. Of all 19 student fatalities, 8 (42%) occurred during the first four jumps with manual deployment of the parachute after initial training with automatic deployment. Twelve (63%) of the 19 student fatalities were related to parachute activation with unstable body position or general freefall instability, leading to no or too low parachute activation, or entanglement with the deploying parachute. This group included the case who caught the deploying reserve parachute around his neck (Table 3; Fig. 3).

Fourteen of the 31 fatalities attributed to ground/water deceleration were students. Of the five drowning incidents, four were students and one a licensed skydiver.

All seven female fatalities had 3 years in the sport or less, and less than 200 jumps. Of the 30 male fatalities, 4 had 6 years in the sport or more and 7 had more than 200 jumps (Table 3). Of female fatalities, three were students in training and four were licensed skydivers.

Thirteen cases could be confirmed as having made less than 10 jumps during the 3 months preceding incident. Of those, 11 were students, 3 of which were doing their first jump.

4.5. Drugs and alcohol

Two cases of alcohol inebriation were found among the 22 post mortem autopsy records, having blood alcohol concentrations of 0.3 and 0.29 g/L, the latter with a urine alcohol concentration of 0.19 g/L. No other recreational or significant prescription drug could be verified in the present material.

Photo courtesy of Magnus Caro.

Fig. 3. Student skydiver in dangerously unstable body position, with a river below.

4.6. Equipment

The Swedish Parachute Association has always required use of a skydiving harness that carries two separately packed parachutes, a main and a reserve. No case of harness malfunction (such as rupture or the like) was found. Six (16%) cases of immediate primary main parachute malfunction were found, excluding malfunctions induced by entanglement or after having operational parachute (Fig. 1). Four of these six were licensed skydivers and two were students. No obvious common technical attribute was found. Four primary main parachute malfunctions were followed by failure of the skydiver to activate the reserve parachute at sufficient altitude. A total of 21 (57%) cases showed no or too low reserve parachute activation. No conclusive case of primary reserve parachute malfunction was found, but in two cases, investigation speculated if an unstable body position had resulted in a delayed deployment of the reserve. Both of these cases left important technical questions unanswered as the investigation material was inconclusive. In one case, it was speculated whether the belly-mounted reserve did not open as a result of the skydiver having assumed a fetal position. In the other case, it was speculated whether the reserve did not inflate because the malfunctioning main parachute lines entangled with the reserve container as the skydiver fell back-to-earth. In the later case, the reserve parachute container was placed on the back of the skydiver alongside the main parachute container in one integrated backpack, as became standard during the 1980s.

Twelve (32%) of all fatalities had an inflated and operational parachute at some point prior to injury, capable of preventing landing injury. Of those 12 cases, 5 were drownings after water landing, 2 were incorrect disconnections of an operational main parachute without subsequent reserve activation at sufficient altitude, 2 were low altitude midair wing parachute collisions at separate instances, 1 was an entanglement into antecedently operational wing parachutes during a planned docking in flight, 1 was a tree-landing outside the designated landing area with a subsequent fall of 5 m and 1 was a radical low altitude wing parachute maneuver.

During the 1970s and 1980s, round canopies were replaced by steerable wing parachutes (Fig. 4). Six earlier fatalities were students jumping round parachutes in high ($\geq$5 m/s) wind speeds, including two of the drowning incidents and the tree-landing. Only one of the total five drownings involved a wing parachute, when after main parachute deployment the student turned the wrong way and landed in a lake.

Suspected failure or inappropriate operation of an automatic parachute activation device was found in five cases, the latest in 1984. In two cases of drowning, automatic activation devices were activated by water landing and deployed the reserve, with subsequent line entanglement being a contributing incident mechanism in at least one of the cases.

Two cases of malfunctioning life jackets were found among the five drowning incidents. Both cases were pulled down under water by the parachute equipment.

4.7. Month and time of day

May showed highest number (7) of fatalities. Time of day could be obtained in 29 incidents. All occurred between 10 a.m. and 9 p.m. and the hour showing highest number of

Photo courtesy of Jeffry L. Wragg, Hans Berggren and Hans Ingmansson.

Fig. 4. Evolution of skydiving equipment. During the 1970s and 1980s, round canopies packed in bulky harnesses with belly-mounted reserves (top) were succeeded by steerable wing parachutes with the main and reserve parachutes both packed into one compact backpack (bottom).

fatalities was between 10 and 11 a.m. with six incidents. Four of these six were licensed skydivers, but had no other obvious common attribute. No conclusive data regarding number of jumps in correlation to time of day or time of year could be obtained.

4.8. Hart–Griffith skydiving fatality taxonomy

Results using the Hart–Griffith skydiving fatality taxonomy (Table 1) were not fully conclusive, as the raters disagreed on categorization of six (16%) fatalities. This was higher than reported for the United States material (Hart and Griffith, 2003). The most important incident categories found were "incorrect procedures" and "no pull/low pull". Three of the disagreements regarded whether students failing to achieve or maintain a stable body position should be defined as an operator error or not.

5. Discussion and conclusions

Incomplete world injury data showed the fatality rate in relation to the total number of jumps in 33 countries during 2002 to be 1.6 times higher than the Swedish 1994–2003 (International Parachuting Commission, 2003). Thus, Sweden appears to be a relatively safe country for skydiving in general, but with a poor fatality record for student training. Though exact participant and jump ratios between students and licensed skydivers only could be obtained for the last decade, it still remains that for the time period 1970–1999, 10% of recorded fatalities in the United States Parachute Association were students (United States Parachute Association, 2004), seemingly lower than the Swedish 51% student fatality rate 1964–2003. USPA data were incomplete with ratio of student to licensed jump volume unknown. Between 1956 and 1964, Kiel found one-third of sport parachuting deaths in the United States to have occurred during student training. He also found uncontrolled fall associated with failure to activate the parachute (Kiel, 1965b). Kiel's findings showed a fatality peak for the first and second freefall jump, analogous to our findings, but he did not penetrate this further.

At present, the Swedish parachuting clubs use two different training systems for students. The most common utilizes automatic immediate parachute deployment on exit of the aircraft during the first jumps, and then, as the student develops proper skills, manual deployment with progressively longer and more challenging freefalls. Our study showed a noticeable fatality peak at the switch from automatic to manual deployment, when the students first experience freefall, a sensation somewhat similar to submersion in rapidly flowing water. The airstream produces dynamic forces acting on the body, as can be observed by dropping any asymmetric object from an altitude, and failure to achieve or maintain a stable body position can cast an inexperienced skydiver into violent tumbling in seconds. In many of the Swedish cases, this tumbling led to unstable parachute activation with subsequent line entanglement, or failure to activate either parachute at sufficient altitude.

The other training system, practiced in Sweden since 1984 (Bursell and Rydén, 1984), puts the student into a long freefall at the first jump, but with two instructors alongside in the air to hold and help. One case who caught the deploying reserve parachute around his neck was a student in the latter training system, who became unstable during a reserve deployment sequence following a main parachute malfunction.

Four of the total five drowning incidents were students. Two had defective life jackets and two had none at all. The fifth drowning was a demonstration jump involving a planned water landing, where the experienced skydiver failed to activate his functioning life jacket. Of sport parachuting fatalities in the United States between 1956 and 1964, 19% were drowning incidents (Kiel, 1965b). As in the present Swedish material, a majority of these were unintentional water landings. Today, the United States Parachute Association requires inexperienced licensed skydivers in their progression to higher (B) license to do swimming pool training with parachute equipment, getting out from under parachute and out of harness while treading water (United States Parachute Association, 2004). The Swedish Parachute Association requires no water training for students or licensed skydivers.

As all drownings but one occurred with round parachutes, it could be assumed that the drowning risk has been reduced with the steerable wing parachute. However, considering the long coastline, abundant bodies of water and cold climate, drowning must not be neglected as a risk in Swedish parachuting. The drowning case with a wing parachute was a first-time student who steered the wrong way. An additional water hazard is that some licensed skydivers use weight vests to match fall rates, and helmet-mounted video cameras. Release systems for helmet-mounted video cameras are mandatory, but not for weight vests. Presently, the Swedish Parachute Association requires personal floating devices be worn and a rescue boat be prepared when designated landing area is within 1 km to water deeper than 1 m.

Incomplete world injury data showed "Fast Canopies[1]" to be the most important fatality factor during 2002, encompassing 33% of all known (73) skydiving fatalities in 33 countries, followed by "Other Landing Errors" at 19% (International Parachuting Commission, 2003). During the 10-year period 1993–2002, 33% of all fatalities registered in the United States Parachute Association were associated with (wing) parachute landing, the USPA declaring it "A Decade of Landing Deaths" (Sitter, 2004). This was an effect of more efficient wing parachute designs introduced during the 1990s, capable of achieving vertical or transient horizontal speeds exceeding 100 km/h when operated to the extreme. A temporal increase in landing fatalities in the United States between 1986 and 2001 was shown by Hart and Griffith (2003).

[1] Though wing-shaped, parachutes are often still referred to as "canopies".

This increase in landing fatalities during the 1990s did not occur in Sweden. Only one case could be attributed to the introduction of faster wing parachutes, a misjudged diving turn close to ground in 1993. The total number of Swedish jumps 1994–2003 exceeded 1 million, but no fatality associated with landing of a fully operational parachute occurred in the country during that time period. When faster wing parachutes were introduced in the early 1990s, the Swedish Parachute Association responded with regulations regarding experience level and ratio between weight of parachutist and parachute size, and educational efforts in parachute piloting.

As most of the Swedish cases died with equipment capable of saving their lives, human factors would seem of greater importance than technical. An unfinished Norwegian study attempted to address psychological factors in this context, but did not find conclusive answers before the author fell victim to a fatal skydiving incident related to equipment failure (Johnsen, 1995).

A technological device designed to help when human capacity falls short is the automatic parachute activation device. Throughout most of the time period studied, several models have been available for both the main and reserve parachute. They have been widely used for students, but for many years licensed skydivers preferred not to share parachute activation control with an apparatus. The present findings of several suspected failures, inappropriate operations and water activations of automatic activation devices give this scepticism justification. A paradigm shift came in the early 1990s with a new generation of more reliable automatic reserve activation devices. In 2002, the Swedish Parachute Association made their use mandatory for all skydivers except those having the highest (D) license degree. From our findings of several earlier cases with low or no parachute activation, this preventive strategy appears justified. Road traffic engineering calculates with an average 2.5 s reaction time for a surprised automobile driver (Evans, 1991), corresponding to about 150 m altitude loss in freefall terminal velocity. During the time period studied, the Swedish Parachute Association has raised required minimum altitudes for main parachute activation. The current, 700 m, was enacted in 2002.

Our findings of primary main parachute malfunction contributing in several cases would seem to suggest an incentive to the parachute industry: can parachute design be improved to substantially lessen the incidence of malfunctions?

Though no conclusive case of primary reserve parachute malfunction could be verified in the Swedish fatality material, two cases where an unstable body position delayed reserve deployment were suspect. Reserve parachute deployment systems should not be designed to require a certain body position to function optimally, as they are to be used in the chaotic event of a main parachute malfunction.

It can be noted that in 2003, reserve activation incidence in the Swedish Parachute Association was 123 in 100,000 jumps for all skydivers and 400 in 100,000 jumps for students. That year, students made 9% of all jumps and 29% of all reserve activations. The general instruction for students to activate the reserve on any uncertainty about main parachute integrity (“when in doubt—get it out”) contributed to this discrepancy, as did packing errors.

Results from using the Hart–Griffith skydiving fatality taxonomy had low reliability, considering the high rate of initial rater disagreement. The methodological information given to the raters had been validated through direct correspondence with Christian Hart. One difference compared to the studies by Hart and Griffith was that the smaller Swedish material did not allow as careful training of the raters on actual cases, before the rating was performed.

Nevertheless, both the main incident category found, “incorrect procedures”, and main cause for disagreement between raters, whether students failing to achieve or maintain a stable body position should be defined as operator error or not, using this inter-subjective model indicate that Swedish student training should be an area of acute interest in safety work.

The Swedish Parachute Association states that a skydiver must have had a blood alcohol concentration allowing automobile driving under Swedish traffic regulations (0.2 g/L) at least 8 h prior to jumping. Though not a formal rule, many clubs today do regular, unannounced testing for alcohol and annual narcotics testing of instructors. The two cases with alcohol inebriation, of which the latest occurred during the last 10-year period, indicate that this testing is motivated.

It could be argued that a suicide should have been excluded from the present study. Yet, fatal acts of self-harm appear preventable to some degree by precaution in the skydiving community, and by medical doctors doing pre-course examinations. In this case, the skydiver had written her intention for the jump in her logbook.

During the time period studied, parachuting changed. Some of the hazards facing parachutists in the past and present are incomparable. Flying a modern wing parachute involves other dangers than descending under a round canopy. In society at large, change has taken place with the development of modern trauma care. Some of the earlier cases who died during transports or in hospitals might have had a better chance today, for example a tree-landing with subsequent fall of 5 m, where the skydiver was found conscious complaining about pain in the abdomen, later became unconscious, and died the same night with pelvic fractures and associated internal haemorrhage.

Finally, it would seem appropriate for the present authors to try to answer how dangerous Swedish skydiving is compared to other activities. Though number of jumps translates poorly as denominator, the mean annual fatality rate 1994–2003 of 28 per 100,000 skydivers and year appears roughly comparable to the present motorcycle fatality rate in Sweden of 21 per 100,000 registered motorcycles and year (Swedish Road Administration, 2005). This incidence in relation to number of participants was affected by including the fatality of a Danish skydiver temporarily jumping in Sweden. Two cases of Finnish nationality were permanently jumping in Sweden as members of the Swedish Parachute Association.

Acknowledgments

The authors would like to thank Ola Jameson, Ann Lindberg, Jesper Löfberg, Arne Nilsson, Chippe Lindberg, Fredrik Eriksson, Umberto Perez, Rolf Käck, Bertil Klingwall, Tony Månson, Leif Hilmersson, Kjell Brommesson, Göran Lilja and Bosse Östberg of the Swedish Parachute Association; Jim Crouch of the United States Parachute Association; Brian Germain of the Big Air Sportz; Knut Magne Ekerhovd of the Norwegian Air Sports Federation; Max Bishop of the Fédération Aéronautique Internationale; Margareta Andersson of the Swedish Civil Aviation Administration; Christian Hart of the Department of Psychology, East Central University, OK, USA; Mats Öström and Anders Eriksson of the Department of Forensic Medicine, Umeå University, Sweden; Ann-Sofie Hjelm, Per-Olof Bylund and Pontus Albertsson of the Department of Surgical and Perioperative Sciences, Umeå University, Sweden; Richard Marsell of the Department of Surgical Sciences, Uppsala University, Sweden; Thomas Lekander of the Swedish Road Administration.

References

2002 Safety & AAD Reports, 2003. International Parachuting Commission Technical and Safety Committee, pai@indigo.ie.

Amamilo, S.C., Samuel, A.W., Hesketh, K.T., Moynihan, F.J., 1987. A prospective study of parachute injuries in civilians. J. Bone Joint Surg. Br. 69 (1), 17–19.

Amoroso, P.J., Bell, N.S., Jones, B.H., 1997. Injury among female and male army parachutists. Aviat. Space Environ. Med. 68 (11), 1006–1011.

Amoroso, P.J., Ryan, J.B., Bickley, B., Leitschuh, P., Taylor, D.C., Jones, B.H., 1998. Braced for impact: reducing military paratroopers' ankle sprains using outside-the-boot braces. J. Trauma 45 (3), 575–580.

Baiju, D.S., James, L.A., 2003. Parachuting: a sport of chance and expense. Injury 34 (3), 215–217.

Barrows, T.H., Mills, T.J., Kassing, S.D., 2005. The epidemiology of skydiving injuries: world freefall convention, 2000–2001. J. Emerg. Med. 28 (1), 63–68.

Bricknell, M.C., Craig, S.C., 1999. Military parachuting injuries: a literature review. Occup. Med. (Lond.) 49 (1), 17–26.

Bullock, M.I., 1978. Ripcord release capability of female parachutists. Aviat. Space Environ. Med. 49 (10), 1177–1183.

Bursell, A., Rydén, F., 1984. Bra komplettering, men ingen cirkus. Svensk Fallskärmssport 13 (3), 18–19 (in Swedish).

Ciccone, R., Richman, R.M., 1948. The mechanism of injury and the distribution of three thousand fractures and dislocations caused by parachute jumping. J. Bone Joint Surg. (Am.) 30, 77–97.

Dawson, M., Asghar, M., Pryke, S., Slater, N., 1998. Civilian parachute injuries; 10 years on and no lessons learned. Injury 29 (8), 573–575.

Ellitsgaard, N., Cuadros Ellitsgaard, V., Ellitsgaard, C., 1989. Injury producing factors in sport parachuting. J. Sports Med. Phys. Fitness 29 (4), 405–409.

Ellitsgaard, N., 1987. Parachuting injuries: a study of 110,000 sports jumps. Br. J. Sports Med. 21 (1), 13–17.

Ellitsgaard, N., 1988. Fractures sustained by civilian parachutists in Denmark. Ugeskr. Laeger 150, 18–20 (in Danish).

Evans, L., 1991. Traffic Safety and the Driver. Van Nostrand Reinhold, New York.

Essex-Lopresti, P., 1946. The hazards of parachuting. Br. J. Surg. 34, 1–13.

Hart, C.L., Griffith, J.D., 2002. A summary of US skydiving fatalities: 1993–1999. Percept. Mot. Skills 94, 1089–1090.

Hart, C.L., Griffith, J.D., 2003. Rise in landing-related skydiving fatalities. Percept. Mot. Skills 97 (2), 390–392.

Hilfiker, R., Badan, J.M., Bishop, M., Worth, B.J., 2002. Parachuting, Skydiving ... Sports Above All. Fédération Aéronautique Internationale, Lausanne.

Johnsen, J.H., 1995. Personality and Prediction in Aviation (unfinished study by G. Jan Meyer in 2002). Compiled by Breivik, Hemet, CA.

Kiel, F.W., 1965a. Survey of military sport parachuting deaths. Aerosp. Med. 36, 360–362.

Kiel, F.W., 1965b. Parachuting for sport. Study of 100 deaths. JAMA 194 (3), 264–268.

Knapik, J.J., Craig, S.C., Hauret, K.G., Jones, B.H., 2003. Risk factors for injuries during military parachuting. Aviat. Space Environ. Med. 74 (7), 768–774.

Lord, C.D., Coutts, J.W., 1944. Typical parachute injuries. JAMA 125, 1182–1187.

Lucas, J., 1997. The Silken Canopy: A History of the Parachute. Airlife, Shrewsbury.

Mellen, P.F., Sohn, S.S., 1990. Military parachute mishap fatalities: a retrospective study. Aviat. Space Environ. Med. 61 (12), 1149–1152.

Petras, A.F., Hoffman, E.P., 1983. Roentgenographic skeletal injury patterns in parachute jumping. Am. J. Sports Med. 11 (5), 325–328.

Ryan, A.J., Thomas, C.L., 1965. Sport parachuting and sky diving. JAMA 194, 259–263.

Schumacher, J.T., Creedon, J.F., Pope, R.W., 2000. The effectiveness of the parachutist ankle brace in reducing ankle injuries in an airborne ranger battalion. Mil. Med. 165 (12), 944–948.

Sitter, P., 2004. Parachutist 45 (4), 36–45.

Steinberg, P.J., 1988. Injuries to Dutch sport parachutists. Br. J. Sports Med. 22 (1), 25–30.

Swedish Road Administration, 2005. www.vv.se (in Swedish).

Tobin, W.J., Cohen, L.J., Vandover, J.T., 1941. Parachute injuries. JAMA 117, 1318–1321.

United States Parachute Association, 2004. www.uspa.org.